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Implementation of Controlled Robot for Fire Detection and Extinguish to Closed Areas Based on Arduino

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Abstract

The wireless control systems are taking a special importance in the recent years, where the wireless control system provide several advantages; including the disposal of the using wire and periodic maintenance of data transmission wires, in the science of robot wireless control unit is the main part of the fire treatment and extinguish robot system. The lives of firefighters exposed to the risk of death and Rima, therefore the use of remote control systems more secure is necessary. In this, paper a fire-extinguish robot used for extinguishing the fire in general and in treatment fires in the closed areas for protecting employees in the field of fire suppression from combustion, exposure or inhalation to the toxic gases. The basic idea of fire detection and treatment robot based on detect the fire by the wireless camera and flame sensor then suppression the fire by send command from mobile phone through Bluetooth connection to make water pump turn "ON", and the fire then extinguished.

Keywords: *arduino, wireless control system, fire-extinguishing robot, flame sensor, wireless camera, bluetooth*

1. Introduction

Recently, there was a lot of risk on the workers in the field of fire extinguishing. The fire-fighting robots can be used to protect fire-extinguishing personnel of the risk of combustion and inhalation of toxic gases and explosive materials, especially in confined areas and narrow. This robots leading to the maintenance of life of workers in the field of fire extinguishing. A robot system is an electromechanical device used in science or industry to replace of a human work or to carry out the functions assigned to him. It can interact with its environment; sometimes it may resemble a human being physically or carry out its tasks in a human way. In general, the more sophisticated and individualized machine, it is to be likely classed as a robot device [1].

Mobile Robots: is a system capable of moving their bodies from place to another in its environment. Mobile robots come in two varieties: tethered and autonomous. A tethered robot by dumping its power supply and brain overboard, possibly relying on a desktop computer and a wall outlet. Control signals and power are run through a bundle of wires (the tether) to the robot, which is free to move around, at least as far as the tether will allow [2].

Autonomous mobile robots: These varieties of robots are necessity to bring everything along with them, including a power supply and a brain. The power supply is usually many batteries, which adds a lot of weight to the robot. The brain is also bounded because it must fit on the robot, and be thrifty about absorption power out of the batteries. [3].

Today Robotics has performed greatest success in the world of industrial manufacturing. Robot legs or mechanical hands are more flexible and can move at any specific position in the assembly line, the robot leg can move very fast with accuracy to perform repetitive tasks such as painting and welding.

However, with all these successes, the commercial robots suffer from a fundamental disadvantage: lack of mobility. A fixed leg has a limited range of movement, which depends on where it pulled down. In other hand, a mobile robot would be able to movement throughout the manufacturing plant, applying flexibly their talents wherever it is most effective [4]-[5].

A mobile robot is system, which has following functional characteristics:

a. Mobility: total mobility relative to the environment.
b. A certain level of autonomy: limited human interaction.

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c. Perception ability: sensing and reacting in the environment.

All mobile robots can move from one place to another, they need to be able to move forward, backward, and to turn to the left or right. Robots are often operated in narrow spaces therefore it useful to be able to revolves around one spot. Variable speed is less important and often unnecessary [6].

A mobile robot needs locomotion (movement); is a mechanism that use to move unrestrained throughout its environment. However, there are vast several of possible ways to move, and so, the important thing that needed to design a mobile robot is a robot's approach to locomotion.

Mobile robots generally can move either by using wheeled mechanisms, like technology for vehicles, or by using articulated legs, the simplest of the biological approaches to locomotion [7]. In general, legged locomotion requires higher degrees of freedom when compared with wheeled locomotion and therefore greater mechanical complexity.in addition to being simple; it is suitable very well to the flat ground.

In effect, the wheeled locomotion efficiency depends greatly on environmental qualities, especially with the flatness and hardness of the ground, while the of legged locomotion efficiency depends on the leg mass and body mass, both must support a robot in various points in a legged gait. Locomotion is the complement of manipulation. In manipulation, the robot arm is fixed but moves objects by imparting force to the environment. In locomotion, the environment is fixed and the robot moves by imparting force to the environment. In both cases, the scientific basis is the study of actuators that generate interaction forces, and mechanisms that implement desired kinematic and dynamic properties. Locomotion and manipulation thus share the same core issues of stability, contact characteristics, and environmental type.

Stability mean a number and geometry of contact points, Center of gravity, Static/dynamic stability, and Inclination of terrain. Characteristics of contact are; Contact point/path size and shape, Angle of contact, Friction Type of environment structure and medium, (e.g. water, air, soft or hard ground). The starting point of theoretical analysis of locomotion begins with mechanics and physics. Therefore, from this theory; we can formally define and analyze all types of mobile robot locomotion systems [8].

1.1. Legged Locomotion

Legged locomotion is characterized by a series of point contacts between the robot and the ground. The key advantages include adaptability and maneuverability in rough terrain. Because only a set of point contacts is required, the quality of the ground between those points does not matter so long as the robot can maintain adequate ground clearance .In addition, a walking robot is capable of crossing a hole or chasm when the robot exceeds the width of the hole. A final advantage of legged locomotion is the potential to manipulate objects in the environment with great skill. The main disadvantages of legged locomotion include power and mechanical complexity. Also, the leg, include several degrees of freedom, must be capable of sustaining part of the robot's total weight and must be capable of lifting and lowering the robot. Additionally, high maneuverability will only be achieved if the legs have a sufficient number of degrees of freedom to impart forces in a number of different directions. Figure 1 shows an arrangement of the legs of various animals [9].

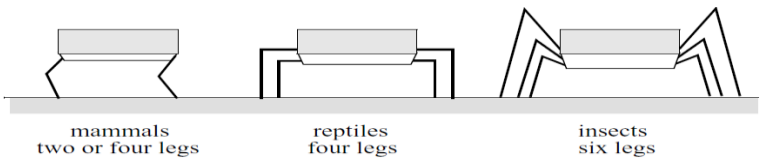

Figure 1. Arrangement of the legs of various animals

1.2. Wheeled Mobile Robots

Wheeled Mobile Robots (WMRs) have been an active area of research and development over the past three decades. This term interest has been mainly Provide by the ample of practical applications that can be uniquely addressed by mobile robots due to their

ability to work in large domains .The wheel was the most popular locomotion mechanism in mobile robotics and in man-made vehicles.so It can perform excellent efficiencies, and does so with a relatively simple mechanical implementation. In addition, wheeled robot designs. Balance is not usually a research problem, because wheeled robots designed in all times the wheels in contact with the ground. Thus, three wheels are sufficient to guarantee stable balance, although, two-wheeled robots can be stable. When more than three wheels are used, a suspension system is required to allow all wheels to maintain ground contact when the robot encounters uneven terrain. We don't need to worry about balance, in wheeled robot research tends to focus on the problems of traction and stability, maneuverability, and control: can the robot wheels provide sufficient traction and stability for the robot to cover all of the desired terrain, if you want to choose the wheels, mobile robot types must focus on wheels' arrangement or wheels geometry. The mobile robot designer must consider these two issues simultaneously when designing the locomotion mechanism of a wheeled robot [10].

Mobile robots are designed for applications in a wide variety of circumstances. Unlike automobiles, which are largely designed for a highly standardized environment (the road network), Automobiles all share similar wheel configurations because there is one region in the design space that maximizes maneuverability, controllability, and stability for their standard environment. However, there is no single wheel configuration that maximizes these qualities for the variety of environments faced by different mobile robots. Like a single-legged hopping machine, it can never stand still. Nevertheless, this table provides an indication of the large variety of wheel configurations that are possible in mobile robot design. For instance, the two-wheeled bicycle arrangement has moderate maneuverability and poor controllability. Like a single-legged hopping machine, it can never stand still. Nevertheless, this table provides an indication of the large variety of wheel configurations that are possible in mobile robot design [11].

1.3. Maneuverability

Some robots are omnidirectional, which means the robots can move in all directions at any time along the ground plane (x,y) without care about the orientation of the robot around its vertical axis. This level of maneuverability needs wheels that can move in more than one direction and so omnidirectional robots usually need to use Swedish or spherical wheels that are powered. A good example is Uranus, shown in Figure 2. This robot uses four Swedish wheels to rotate and translate in isolation and without constraints [12].

Figure 2. The Carnegie Mellon Uranus robot

There is no ideal drive configuration that simultaneously maximizes stability, typically inverse correlation between controllability and maneuverability for example, the omnidirectional designs like the four-castor wheel arrangement need to significant processing to convert desirable rotational and translational quickness to individual wheel commands Furthermore, this omnidirectional design sometimes have greater degrees of freedom at the wheel. For instance, the Swedish wheel has a set of free rollers along the wheel perimeter. Because of These degrees of freedom an accumulation of slippage occurs, which tend to decrease dead-reckoning accuracy and increase the design complexity [13].

There is a more difficult for controlling an omnidirectional robot for a specific direction of travel and often less accurate when compared to less maneuverable designs. For example, an Ackerman steering vehicle can go straight simply by locking the steerable wheels and driving the drive wheels. In a differential-drive vehicle, the two motors attached to the two wheels must drive along exactly the same velocity profile, which can be challenging considering differences

between wheels, motors, and environmental differences. With four-wheel Omni drive, such as the Uranus robot, which has four Swedish wheels, the problem is more difficult because all four wheels must drive at the same speed for the robot to travel in a perfectly straight line.

In summary, there is no "ideal" drive configuration that simultaneously maximizes stability, maneuverability, and controllability. Each mobile robot application places unique constraints on the robot design problem, and the designer's task is to choose the most appropriate drive configuration possible from among this space of compromises.

Kinematics this term means the basic study of how mechanical systems behave. In mobile robotics, if you need to understand the mechanical behavior of the robot must know design appropriate mobile robots for tasks and how to create control software for an instance of mobile robot hardware [14].

2. Arduino

An Arduino is a single-board microcontroller and a software suite for programming it to been embedded system. The hardware consists of a simple open hardware design for the controller with an Atmel AVR processor and on-board I/O support. The software consists of a standard programming language and the boot loader that runs on the board. In other words, an Arduino is a tiny computer that you can program to process inputs and outputs between the device and external components you connect to it [15].

The Arduino board is where the code you write is executed. The board can only control and respond to electricity, so specific components are attached to it to enable it to interact with the real world. These components can be sensors, which convert some aspect of the physical world to electricity so that the board can sense it, or actuators, which get electricity from the board and convert it into something that changes the world. Examples of sensors include switches, accelerometers, and ultrasound distance sensors. Actuators are things like lights and LEDs, speakers, motors, and displays [16]. Pulse Width Modulation is a process that is used in many applications. One of the easiest ways to execution this is by using an Arduino. This application note will look at what Pulse Width Modulation is and will explain how to perform Pulse Width Modulation using two different methods. The Arduino can do this in several ways. Figure 3 shows some of Arduino types

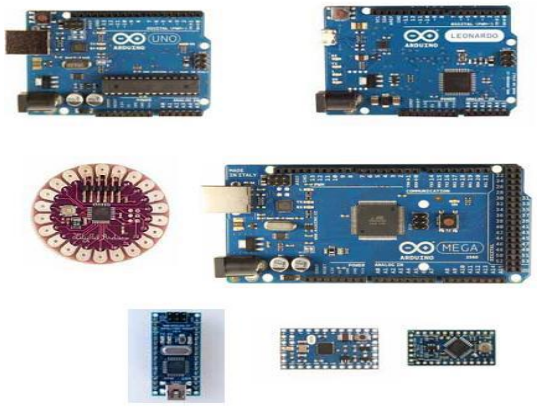

Figure 3. Some arduino families

3. The Fire Detection and Extinguish Robot to Closed Areas Based on Arduino

3.1. Arduino Uno

The Arduino UNO is a board based on the ATmega328 microcontroller. The Arduino Uno can be supply it via the USB connection or with an external power supply. The power source is selected automatically, It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino has the ability to re-programming since it is an

open-source electronics prototyping platform. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts see Figure 4 [17].

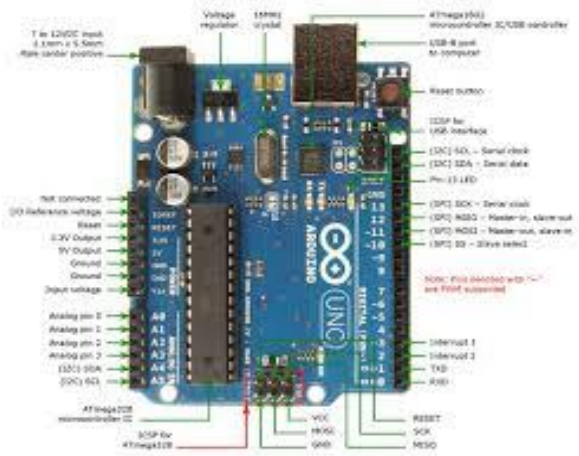

Figure 4. Arduino UNO Kit

Specifications are;14 digital pin used for digital I/O, 6 analog pin used for analog input,16MHZ processor speed, Microcontroller aTmega328, 32KB memory size and from digital pins there are 6pins used for PWM.

3.2. DC Motor for Car Prototype

Figure 5 shows a DC motor used for the car robot prototype. This motor has working voltage of (3V-6V); it is a gear motor that is use to rotate a tire connected to it. This DC motor comes with single axis and a RPM of 125R / minute, the gearbox is applied for tracing car or robot. With plastic construction and colored in bright yellow, the DC gear motor measures approx. 2.5-inch-long, 0.85-inch-wide and 0.7 inch thick [18].

Figure 5. DC Gear Motor

3.3. L298 Motor Driver

The L298 motor driver, Figure 6, is an H-bridge Dual Motor Controller. H-Bridges in general used in the purpose of controlling motors for speed and direction control purpose. An H-Bridge is a circuit that can drive a current in either polarity, and can be controlling by Pulse Width Modulation (PWM). The most usual control method of a Dc motor rpm consists of the control through the applied voltage. The one way of controlling the applied voltage called pulse width modulation (PWM),the motor rpm variation is performed by increasing or decreasing the time interval when the control signal has the logic value 1 (TON) continuously this meaning the duty cycle 100%. The motor will have the maximum rpm, TON will be maximal and TOFF will be zero. At a duty-cycle of 50 %, the motor will have half the rated rpm, so TON = TOFF. In case of a duty-cycle of 0%, the motor will be stopped, so TOFF will be maximal whilst TON will be zero. The duty cycle noted by "D" and can calculated through the relation (1) [19].

$$D = \frac{T_{on}}{T_{on}+T_{off}} *100\% \quad (1)$$

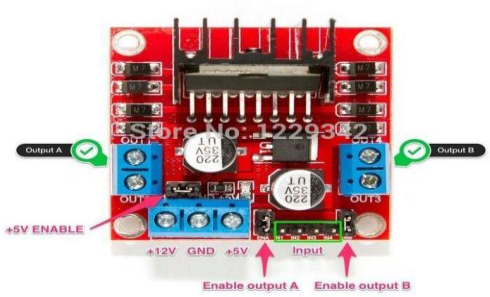

Figure 6. L298 motor driver

In general, the Arduino microcontrollers generate PWM signals, in an electric drive system, micro-controllers form the logic control or decision side and DC motors form the acting side. The control side usually operates with 5V and low power, the acting side operates with higher voltage and rated power. For this purposes an interface is necessary between the two parts of the system, the increased in PWM offset by an increase in output voltage the 100% duty cycle means the full voltage level as shown in Figure 7 [20].

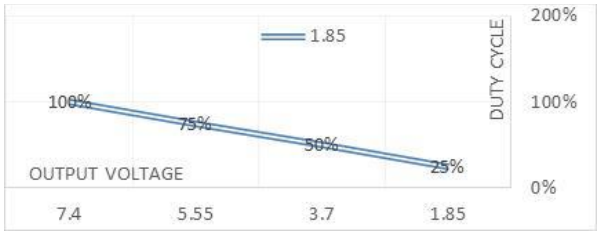

Figure 7. Relation between duty cycle and output voltage

3.4. Bluetooth HC-06

Bluetooth is a wireless technology standard it use to exchange data over short distances using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994 .This can used as serial port replacement to establish connection between PC and MCU (Microcontroller). This is a Slave Mode only Bluetooth device. This module can configured for baud rates 1200 to 115200 bps. HC-06 Module Features listed as the following, Figure 8 shows this module of Bluetooth technology [21].

a. Encrypted connection
b. Frequency band : 2.4 – 2.524 GHz
c. Bluetooth core v2.0
d. Serial Port Profile (SPP) support

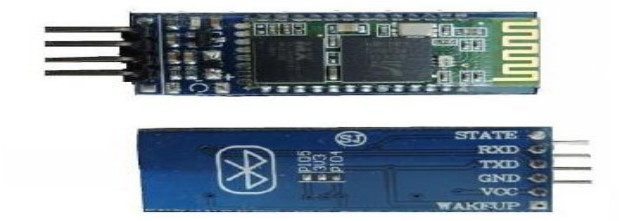

Figure 8. HC-06 bluetooth module

3.5. Flame Sensor

This sensor designed to detect and respond to the presence of a flame. A flame sensor can often detect faster and more accurately than a smoke or heat detector due to the mechanisms it uses to detect the flame. The flame sensor use to detect fire source or other light sources that are in the wavelength in the range of (760nm - 1100 nm). The module consists of an IR sensor, potentiometer, OP-Amp circuitry and a led indicator. In addition, it based on the YG1006 sensor, which is a high velocity and high sensitive NPN silicon phototransistor. When a flame will detected, the module will turn on its red led. This module is sensitive to flame but it can also detect ordinary light. The detection point is 60 degrees. The sensitivity of this sensor is adjustable, it has a stable performance. The Figure 9 shows the flame sensor value over distance, and the figure 10 shows the flame sensor [22].

The flame sensor module has the following features.

a. The operating voltage is from 3.3–5V.
b. It gives us both analog and digital output.
c. It has a led indicator, which indicates that whether the flame is detected or not.
d. The threshold value can be changes by rotating the top of potentiometer.
e. Flame detection distance, lighter flame test can be triggered within 0.8m, if the intensity of flame is high, the detection distance will be increased.
f. The detection angle of the flame sensor module is about 60 degrees.

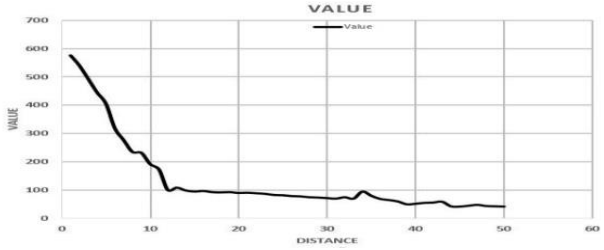

Figure 9. Flame sensor value over distance

Figure 10. Flame sensor

3.6. Car Robot Components

In this project, a simple design of four-wheel car as a remote controlled robot it designed and implemented using the following parameters:

a. Four-wheel car prototype
b. Arduino Uno
c. Motor Driver (L298N)
d. Transistor 2N2222 for switching purpose
e. Flame Sensor
f. Bluetooth (HC-06)
g. RF camera
h. DC water pump
i. LCD screen
j. Rechargeable battery (Li-Ion 2x3.7V)

3.7. Working principle of Fire Detection and Extinguish Robot:

After the wireless connection it established between the Android application with the Arduino Bluetooth and send the commands of motion to the Arduino for starting the operation of

Robot. When the Robot it enters to the place of fire and detected the flame through the camera and the flame sensor, the driver will be sending command from the Android application to the Arduino for making water pump turn "ON" to extinguish the fire. The water pump does not work except in the case of sending the command from the application as well as sensing the sensor, the reason for this because the flame sensor sensitive normal light which wavelength between 760nm-1100nm this will make it more accurate ,let suppose there is a light fire in the room and a dense fire in other room that may be inside it children or any important things we will give the precedence to the important fire so the water will saved, the other thing if the camera is damaged or If the robot hangs in place the sensor will detect the fire and we already send command of operating the water pump will be "ON" state so the fire it extinguished. Figure 11 below shows Block diagram for the whole system. The necessary command for start working and turn on the water pump are shown in the Table 1.

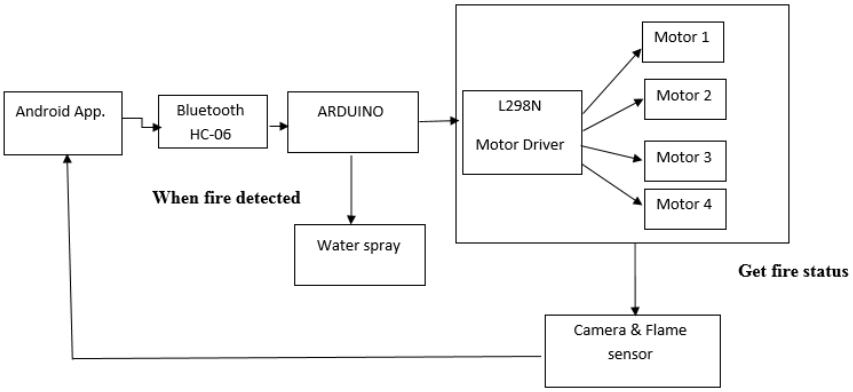

Figure 11. System Block Diagram

Table 1. Commands Required for Starting Operation of Robot

Command	Operation
'F'	Make the robot move forward direction
'B'	Make the robot move backward direction
'R'	Make the robot move toward right direction
'L'	Make the robot move toward left direction
'X'	Turn on the water pump
'x'	Turn off the water pump

Figure 12 shows the monitoring system using wireless camera, LCD monitor and flame sensor.

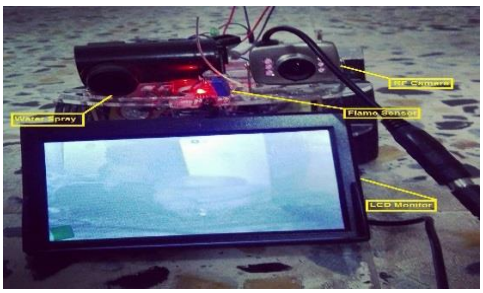

Figure 12. Fire monitoring system prototype

In this system, a water pump is connected to Arduino through transistor and water pipe, the Figure 13 shows the fire extinguisher system using a water pump controlled by Arduino.

Figure 13. Fire extinguisher system prototype

The system over all controlled using a special application works in Android environment shown in Figure 14.

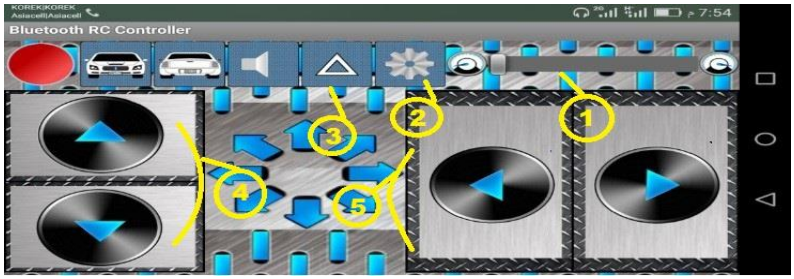

Figure 14. System controlling software

The Table 2 shown describe the functions of the android application buttons corresponding to the shown numbers in Figure 14.

Table 2. Functions of Android App. Buttons

Number	Function
1	This scroll responsible on the speed control of the motors of robot.
2	To connect to the robot via Bluetooth.
3	To run the water pump for extinguishing the fire.
4	Forward and Backward direction.
5	Right and Left direction.

4. Results

The initial stage of the project is the part of finding fire, by the flame sensor and the wireless camera, the fire sensor and wireless camera detects the fire at a certain distance. It does not receive data from areas outside of the determined area. The wireless control of the robot it established via HC-06 Bluetooth and android application when the robot navigating the fire then the driver of robot send the necessary command to make the water pump turning "ON" and the fire becomes controlled and can extinguish it as shown in Figure 15.

Figure 15. Extinguishing the fire detected by the robot

5. Conclusion

A simple fire detector and extinguisher robot is designed using Arduino based Microcontroller, the wireless camera and flame sensor used for fire detecting. After the fire detected then extinguished by the water pump. The aim of this work to develop a mobile robot it specially used to extinguish indoor fires that are difficult to reach easily. The mobile robot which is designed as a result of this study communicates with the mobile phone through the serial port via the serial port and processes the analog data received from the flame sensor in the microcontroller control so as to determine the fire in the environment while determining the fire in the environment. In this work, a system that works successfully both hardware and software has been realized. This work can be improve by:

a. Designing the robot to work independently of human (automatically).
b. More sensors can be used with the robot (such that gas sensor and toxic gages sensors).
c. Using XBee or Wi-Fi techniques instead of Bluetooth to extend the controlling area.
d. Using Wi-Fi camera to increase the monitoring area.

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